VOLUME 79 SEPARATE No. 172

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

FEBRUARY, 1953

AERONAUTICAL CHARTING AND MAPPING

By Charles A. Schanck

SURVEYING AND MAPPING, AIR TRANSPORT DIVISIONS

Headquarters of the Society
33 W. 39th St.
New York 18, N.Y.

PRICE $0.50 PER COPY

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Technical Division	*Proceedings-Separate Number*
Air Transport	108, 121, 130, 148, 163, 172, 173, 174 (Discussion: D-23, D-43, D-75, D-93, D-101, D-102, D-103, D-108, D-121)
City Planning	58, 60, 62, 64, 93, 94, 99, 101, 104, 105, 115, 131, 138, 148, 151, 152, 154, 164, 167, 171, 172, 174 (Discussion: D-65, D-86, D-93, D-99, D-101, D-105, D-108, D-115, D-117)
Construction	154, 155, 159, 160, 161, 162, 164, 165, 166, 167, 168 (Discussion: D-75, D-92, D-101, D-102, D-109, D-113, D-115, D-121)
Engineering Mechanics	142, 143, 144, 145, 157, 158, 160, 161, 162, 169 (Discussion: D-24, D-33, D-34, D-49, D-54, D-61, D-96, D-100, D-122, D-125, D-127)
Highway	138, 144, 147, 148, 150, 152, 155, 163, 164, 166, 168 (Discussion: D-103, D-105, D-108, D-109, D-113, D-115, D-117- D-121)
Hydraulics	141, 143, 146, 153, 154, 159, 164, 169, 175 (Discussion: D-90, D-91, D-92, D-96, D-102, D-113, D-115, D-122)
Irrigation and Drainage	129, 130, 133, 134, 135, 138, 139, 140, 141, 142, 143, 146, 148, 153, 154, 156, 159, 160, 161, 162, 164, 169, 175 (Discussion: D-97, D-98, D-99, D-102, D-109, D-117)
Power	120, 129, 130, 133, 134, 135, 139, 141, 142, 143, 146, 148, 153, 154, 159, 160, 161, 162, 164, 169, 175 (Discussion: D-96, D-102, D-109, D-112, D-117)
Sanitary Engineering	55, 56, 87, 91, 96, 106, 111, 118, 130, 133, 134, 135, 139, 141, 149, 153, 166, 167, 175 (Discussion: D-96, D-97, D-99, D-102, D-112, D-117)
Soil Mechanics and Foundations	43, 44, 48, 94, 102, 103, 106, 108, 109, 115, 130, 152, 155, 157, 166 (Discussion: D-86, D-103, D-108, D-109, D-115)
Structural	133, 136, 137, 142, 144, 145, 146, 147, 150, 155, 157, 158, 160, 161, 162, 163, 164, 165, 166, 168, 170, 175 (Discussion: D-51, D-53, D-54, D-59, D-61, D-66, D-72, D-77, D-100, D-101, D-103, D-109, D-121, D-125, D-127)
Surveying and Mapping	50, 52, 55, 60, 63, 65, 68, 121, 138, 151, 152, 172, 173 (Discussion: D-60, D-65)
Waterways	120, 123, 130, 135, 148, 154, 159, 165, 166, 167, 169 (Discussion: D-8, D-9, D-19, D-27, D-28, D-56, D-70. D-71, D-78, D-79, D-80, D-112, D-113, D-115)

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Published at Prince and Lemon Streets, Lancaster, Pa., by the American Society of Civil Engineers. Editorial and General Offices at 33 West Thirty-ninth Street, New York 18, N. Y. Reprints from this publication may be made on condition that the full title of paper, name of author, page reference, and date of publication by the Society are given.

Proceedings—Vol. 79 February, 1953 Separate No. 172

AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

PAPERS

AERONAUTICAL CHARTING AND MAPPING

By Charles A. Schanck[1]

Synopsis

Charting and mapping standards of the United States Coast and Geodetic Survey are outlined in this paper. Special charts needed by the aviator and by those who lay out air transport lanes and terminal facilities are classified. Among the specialty maps described are the "Sectional Aeronautical Charts of the United States," world aeronautical charts, small landing charts, and the related problems of assembling data for such purposes.

Introduction

The aeronautical charting program of the Coast and Geodetic Survey, U. S. Department of Commerce (USCGS), was initiated in about 1930 to provide necessary charts for aviation. Progressive cartographic developments in the nautical charting work of the USCGS, covering a period of more than 100 yr, have resulted in improved charting techniques that have given the nautical chart its present high standard in precision, and its scientific status. Because of the basic similarity between nautical and aeronautical charts, the production of the latter was also delegated to the USCGS as a result of the Air Commerce Act of 1926 and subsequent legislative action.

The need for special maps or charts for air navigation was realized as early as 1888 when steps were taken in Europe to produce maps for the navigation of lighter-than-air craft. With the limited air speeds of the early days of aviation, it was possible for the aviator to use standard topographic maps for identifying prominent landmarks in navigating his plane. The British incorporated special features into an "aero" map produced in 1912 to emphasize details pertinent to the aviator. This early aeronautical map emphasized roads, railways, and lakes by hand coloring on a photoprint of an ordinance survey map at a scale of 1 in. = 1 mile.

The practice of using existing topographic maps, with the addition of special information by hand, continued during the early days of World War I, but

Note.—Written comments are invited for publication; the last discussion should be submitted by August, 1953.

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the growth of aviation during that war emphasized the need for special air maps. By the end of the war, the British had produced special air charts for use over the coastal areas of the British Isles and a special aviation map of France. These maps are thought to be the first ever produced in quantity for use in the air. They conformed generally to existing topographic maps except in the simplification of certain detail and the showing of aeronautical data, such as aerodromes, landing areas, and dangers to navigation. Air speeds were slow, with flying largely confined to good weather, and navigation was mainly by contact flying or piloting.

An important development in the period immediately following World War I was the International Convention of Air Navigation held in 1920 for the purpose of standardizing cartographic practice to simplify the problems of the aviator when flying outside his own country. General aeronautical charts at the scale of 1:1,000,000, with larger scales for selected areas, were proposed and standard symbols for showing aeronautical data were agreed upon. Existing topographic series, such as the "International Map of the World," were adapted for use in the air by means of an aeronautical overprint. These overprints showed aerodromes, landing areas, dangers, obstructions, prohibited areas, lines of magnetic declination, and radio data. The overprint was reproduced in a conspicuous color, such as red or purple, but was printed so as not to obliterate existing detail on the map.

Charting in the United States

In the United States, the Army Air Corps first considered the needs for aeronautical charts in the early 1920's. When F. L. Martin and his crew made their round-the-world flight in 1924, they accomplished their mission without the aid of aeronautical charts. The flight was made with road maps, topographic maps, nautical charts, and other types—all that were then available. This undertaking and other activities emphasized the need for special charts for use in aviation, and in 1924, the Air Corps inaugurated a project which included 35 strip maps for military use covering limited areas of operation, primarily between major Air Corps fields. The USCGS cooperated with the Air Corps in this undertaking by organizing its first unit for the preparation of aeronautical charts. This unit produced a number of strip maps covering areas 80 miles wide along principal airways to meet immediate demands. In 1927, the printing order for strip maps was increased to 500 copies, which represented a full year's supply.

In 1929, the Federal Board of Surveys and Maps recognized the problem, appointing a committee on aerial navigation maps to make recommendations for a charting program. Work was started in 1930, by the USCGS, on the first of the Department of Commerce charts. The first series was laid out on an area basis to cover the United States in 87 charts known as the "Sectional Aeronautical Charts of the United States." The Chicago (Ill.) chart, published in December, 1930, was the first to be issued of the new series. By 1935, all 87 charts were completed and the Air Corps in the meantime discontinued the use of strip maps in favor of the new sectional charts.

The present-day aeronautical charting activities of the USCGS include the compilation and printing of aeronautical charts of the United States, its territories and possessions, as required for civil aviation and for military use where these requirements are parallel. In addition, such aeronautical charts covering international airways as are required primarily by the United States civil aviation are compiled and printed by the USCGS.

Aeronautical charts on issue in 1952 totaled 1,191, including 276 standard and auxiliary charts, 761 instrument approach and landing charts, and 154 radio facility charts. Approximately 9,000,000 copies of the standard aeronautical charts are distributed annually. In addition, more than 29,000,000 of the page-size airport and radio facility charts are issued each year. These charts are issued in several different types and scales depending on their use. Charts in use for the United States in 1952 included the sectional series at the scale of 1:500,000; 43 world aeronautical charts at the scale of 1:1,000,000; route charts at the scale of 1:2,000,000; and planning, direction-finding, local, instrument-approach and landing, radio-facility, and aircraft-position charts at varying scales.

The sectional charts are considered as the basic all-purpose series designed by the USCGS for contact flying, or flying by reference to visible landmarks. For this reason, they include all prominent topographic features that can be seen from the air, all air navigation aids, and many outstanding landmarks and other items of value to pilots which do not appear on conventional topographic maps.

The world aeronautical charts, at the scale of 1:1,000,000, were designed primarily for radio navigation and, being at a smaller scale, do not show the completeness of detail appearing on the sectional charts. The route charts were designed especially for long-range navigation to meet the requirements of air carriers operating at high altitudes with high-speed aircraft. Aeronautical charts for radio direction finding at the scale of 1:2,000,000 have been constructed for simple and quick plotting of radio bearings. Planning charts of the United States and Alaska at the scale of 1:5,000,000 are published for planning routes between distant points.

The small approach and landing (AL) charts serve the needs of the pilot when approaching an airport on instruments under conditions of low visibility. They also serve as contact charts, after a breakthrough on instruments, and as airport vicinity charts. Charts of the series are published for use with instrument-landing systems and automatic direction-finding equipment. Each type of chart has its primary purpose and has been developed after careful study has been made of the problems involved.

Aeronautical Chart Production

Aeronautical charts constitute a new development in cartography with the primary objective of providing for the needs of the aviator in as simple and characteristic a form as possible. Primary requirements are the ready solution of certain problems of direction and distance and a comprehensive indication of intervening terrain which may be gained at a glance. The features to be stressed are those relevant to air navigation in a rapidly moving plane. The

airway route should be clearly defined, and prominent landmarks either natural or otherwise conspicuous—such as the general trend of railways and highways, their intersections, and the positions of industrial landmarks—are clearly shown or emphasized. Sinuosities of streams should be generalized, and minor roads and details that may confuse the aviator are omitted. Simplicity is desired so that the aviator may grasp at a glance the relative location of the places in which he is interested and which will serve him in maintaining his course.

From the beginning of a compilation until the final product is placed in the hands of the pilot, it is constantly borne in mind that aeronautical charts are not ordinary maps, but highly specialized charts intended for one purpose—to provide the aviator with the simplest and most accurate instrument for proceeding safely to any chosen destination and for identifying terrain features en route. In keeping with these requirements, many details appearing on ordinary maps are omitted because they would only obscure details of greater navigational importance.

As aeronautical charts require special consideration of geographic fundamentals, the merits of a suitable system of projection and proper control become significant in respect to the facility of laying out courses, fixing features, and measuring distances. Therefore, the first step in aeronautical chart production is the determination of the best framework on which to delineate as true a representation of the earth's surface as is practicable for this purpose. Two properties, both of which are vital in air navigation, are the speed and accuracy with which navigational problems may be solved.

In selecting a projection, these factors must be considered:

(*a*) Correct representation of topographic features visible to the airman by preserving true shapes of physical features, including correct angular relationships and the representation of areas in their correct relative proportions;
(*b*) True scale values for measuring distances; and
(*c*) Representation of great circles as straight lines.

Other factors to be considered are the following:

(*d*) Solution of problems of celestial navigation;
(*e*) Determination of position in the air by dead reckoning from accurate courses and distances;
(*f*) Use of radio bearings for position fixing; and
(*g*) Junctions of all adjacent sheets on the same scale.

Chart Projection

After thorough investigation, the USCGS selected the Lambert conformal conic projection for the aeronautical charts of the United States. This projection permits a perfect junction between any number of charts in any direction. It is unexcelled for scaling distances in all directions for a large geographical area, such as the United States. Azimuths obtained from this projection conform closely to directions on the earth. The Lambert projection affords a simple and satisfactory solution for all problems of dead reckoning,

not excepting the rhumb line; it affords a simple means of practical great-circle navigation; it is well suited for celestial navigation and all problems requiring the plotting of positions; and it is unsurpassed for all types of radio navigation.

The meridians and parallels of the earth are projected upon a cone that intersects the surface of the earth along two standard parallels. The standard parallels on the earth and on the cone coincide and along them the scale is therefore exact. Between the standard parallels, the earth is projected inward upon the cone, and the scale of the cone is somewhat smaller than the scale of the larger earth. Outside the standard parallels, the earth's surface is projected outward, and the scale of the cone is slightly larger than that of the earth. The standard parallels of true scale adopted for aeronautical charts of the United States are latitudes 33° and 45°. The tables have been extended by the USCGS with additional bands for world-wide charting; and the aeronautical charts published of world areas by the U. S. Air Force employ this system of projection.

Marginal scales in statute miles are printed in the borders of the charts and the meridians are graduated for use of the nautical mile. The border scales in statute miles on charts of a scale of 1:1,000,000 series, and larger, are based on the scale of the central parallel of the chart. Consequently, the distances measured by these scales along the central parallel are exact, and the distances between points on opposite sides of the central parallel and equidistant from it are exact also, regardless of the direction between them. Distances can be measured on these projections with surprising accuracy.

The use of a transverse or oblique Mercator projection in the production of aeronautical charts has received considerable attention in the past few years due to the development of great-circle navigation. Projection tables for each five degrees of azimuth have been computed and published, thereby making world-wide coverage, based on this projection, possible. The oblique Mercator projection has excellent properties for air navigation. By selecting the projection table that is nearest in azimuth to that of an air-route scale distortion is kept to a minimum, and for all practical purposes no correction is necessary for radio bearings since all straight lines closely approximate great circles.

The Base of the Aeronautical Chart

When the projection to be used in the aeronautical chart has been selected, the next step is the selection of the source material for the various chart features. One source may be best for roads, another for railroads, another for relief and drainage, and still another for city shapes.

Only a small percentage of the base information that goes into its aeronautical charts originates with the USCGS. This information covers areas adjacent to shore lines where field surveys have been conducted by the USCGS in connection with its natural charting program. Control surveys by the USCGS in the interior serve to verify and augment information from other sources. For most of the base material that goes into the aeronautical charts, the USCGS must rely on the mapping activities of other agencies. The quadrangles established by the U. S. Geological Survey (USGS) are the greatest single source of

topographic information. Accurate, up-to-date, topographic maps, regardless of their source, provide the ideal information for the compilation of the aeronautical chart base. Unfortunately, vast areas of the United States have not been mapped adequately. In these areas, the USCGS relies on information from a wide variety of sources, including county road maps and property maps, railroad plans and profiles, drainage maps, aerial photographs, planimetric maps, trigonometric leveling data, and cadastral surveys and others.

The Aeronautical Overprint

Complete aeronautical data are furnished by the Civil Aeronautics Administration (CAA). These data convert the topographic map into an aeronautical chart. They include accurate locations of airports and auxiliary landing fields, types and facilities of airports, navigational lights, radio ranges, civil airways, high-frequency and low-frequency radio facilities, and other aids, as well as power lines and other obstructions to air navigation.

The Finished Chart

As an expression of natural conditions, the finished chart delineates geographic features and aeronautical information partly in the form of a reduced outline and partly in the form of symbols of various kinds. In addition to the proper use of conventional signs and symbols, attention is given to details such as lettering, balance of chart, and the number and selection of charted details. A critical study is made of the area to be charted in order to secure a selection of details that is simple, representative, and practical. By maintaining a sense of proportion and propriety, the cartographer supplies the artistic element indicative of good charting without sacrificing any essential detail.

To afford maximum legibility and ready identification in the air, aeronautical charts are lithographed in colors. Projection lines, names, roads, and railroads are black; city outlines are yellow; drainage is dark blue; and contours are brown. Gradient tints of one or two shades of green and one to five shades of brown are employed. Aeronautical information is in magenta and offset blue.

Airport Obstruction Plans

In 1945, the CAA requested the USCGS to prepare a new series for a different purpose. Regulations of the CAA prescribed maximum weight limitations for aircraft of transport category. The weight limitations vary with the type of aircraft, and with wind and temperature conditions, as well as with the length, elevation, and gradient of the runway being used, and the locations and elevations of obstructions in the vicinity. It was for the study of these latter factors governing weight limitations that the series of "Airport Obstruction Plans" was designed. The plans are also useful tools for city zoning in the airport vicinity, and for the airport engineer in planning new construction.

Each plan shows the airport runway pattern and the location and elevation of objects in the vicinity of the airport that may be potential hazards to air traffic. These objects are those that extend above several imaginary surfaces,

varying in extent, shape, and elevation. A general note on each plan defines those surfaces.

The official airport elevation and a generalized profile of each runway are also shown on each obstruction plan. The profiles extend outward from the end of each runway to a point just beyond the last potential hazards or to a maximum of 10,200 ft for noninstrument runways and 50,000 ft for instrument runways.

Airport obstruction plans are compiled from accurate field surveys and recent aerial photographs, usually taken with the nine-lens camera. The field survey parties identify on the photographs the features to be shown on the plan. The elevations of these features and of the airport runways, the lengths and azimuths of the runways, and the horizontal control necessary for the compilation of the plan are also determined during the field surveys. The plans are compiled in the Washington, D. C., office of the USCGS from the aerial photographs and the ground survey data, at a scale of 1 in. = 1,000 ft.

Each field survey presents its interesting problems. It should be remembered that obstructions in the approach areas and the conical section are defined by sloping surfaces. The reconnaissance for the identification of an obstruction in these areas requires methods peculiar to airport obstruction surveys. In the parts of the approach areas that are visible from the runway ends, obstructions can be readily identified by setting the glide angle on the vertical circle of the instrument and scanning the horizon. Trial elevations must be taken to identify observations in other parts of the area surveyed. A stereoscopic study of the aerial photographs will reveal areas where obstructions are likely.

Once the obstructions are identified, their elevations are determined by any of a number of suitable methods. No great accuracy is required on such surveys. Permissible elevation tolerances are 15 ft in the conical section, 10 ft in the horizontal area, 1.5 ft in the runway area, and 1.5 ft per 5,000 ft from runway ends in the approach areas.

Future Charting

Requirements for aeronautical charts will be changing continually for years to come. The flying farmers, the pleasure flyers, the crop dusters, and the operators of small chartered planes can be expected to continue the use of the sectional aeronautical charts. These charts will be improved as new types of topographic mapping become available. Meanwhile, the operator of the jet-propelled aircraft operating over long distances at high altitudes and at speeds of many hundred miles per hour becomes less and less interested in topographic detail on this chart, except at the take-off and the landing. New types of charts for use for instrument landing systems are already in use. The cartographer must constantly strive to improve his techniques and devise better methods of presenting these facilities so that the aeronautical charts will keep abreast of the rapid developments in the aviation industry.

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Proceedings-Separate Number	Date Available	Title and Author	Discussion closes
148	Oct., 1952	"Bank Stabilization by Revetments and Dikes," by Raymond H. Haas and Harvill E. Weller	Mar. 1
149	Oct., 1952	"Industrial Waste Treatment in Iowa," by Paul Bolton	Mar. 1
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159	Jan., 1953	"Development of a Flood-Control Plan for Houston, Tex.," by Ellsworth I. Davis	June 1
160	Jan., 1953	"Ice Pressure Against Dams: Studies of the Effects of Temperature Variations," by Bertil Löfquist	June 1
161	Jan., 1953	"Ice Pressure Against Dams: Some Investigations in Canada," by A. D. Hogg	June 1
162	Jan., 1953	"Ice Pressure Against Dams: Experimental Investigations by the Bureau of Reclamation," by G. E. Monfore	June 1
163	Jan., 1953	"A Comparison of Design Methods for Airfield Pavements," Progress Report of the Committee on Correlation of Runway Design Procedures of the Air Transport Division	June 1
164	Feb., 1953	"Water Supply Engineering," Report of Committee on Water Supply Engineering of the Sanitary Engineering Division for the Period Ending September 30, 1951	July 1
165	Feb., 1953	"Design Curves for Anchored Steel Sheet Piling," by Walter C. Boyer and Henry M. Lummis, III	July 1
166	Feb., 1953	"The Design of Flexible Bulkheads," by James R. Ayers and R. C. Stokes	July 1
167	Feb., 1953	"Sewage Disposal in Tidal Estuaries," by Alexander N. Diachishin, Seth G. Hess, and William T. Ingram	July 1
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170	Mar., 1953	"Rapid Computation of Flexural Constants," by Thomas G. Morrison	Aug. 1
171	Mar., 1953	"Unified Mass-Transportation System for New York," by William Reid	Aug. 1
172	Mar., 1953	"Aeronautical Charting and Mapping," by Charles A. Schanck	Aug. 1
173	Mar., 1953	"Electronic Devices in Air Transport," by F. B. Lee	Aug. 1
174	Mar., 1953	"Zoning Maps for Airports," by Benjamin Everett Beavin, Sr.	Aug. 1
175	Mar., 1953	"Design of Side Walls in Chutes and Spillways," by D. B. Gumensky	Aug. 1

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